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Modeling interseismic deformation field of North Tehran Fault extracted from precise leveling observation

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ABSTRACT

The North Tehran Fault (NTF) stands out as a major active thrust fault running for approximately 110 km north of Tehran, the capital province of Iran. It has been the source of several major historical earthquakes in the past, including those in 958, 1665, and 1830. In this paper, interseismic strain accumulation on the NFT was investigated using precise leveling measurements obtained over the time frame 1997–2005. The relationship between surface deformation field and interseismic deformation models was evaluated using simulated annealing optimization in a Bayesian framework. The results show that the NTF fault follows an elastic dislocation model creep at a rate of 2.5 ±0.06 mm/year in the eastern part and 6.2 ±0.04 mm/year in the western part. Moreover, the locking depth of the fault was evaluated to be ±1.1 km in the eastern part and 1.3 ±0.2 km in the western part.

1. Introduction

Tehran lies on the southern flank of the Central Alborz Mountains, an active mountain belt characterized by many historical earthquakes, some of which have affected Tehran itself. The border between the Alborz Mountains and the Tehran piedmont (the northern part of Tehran City) is marked by the North Tehran Fault (NTF), as a thrust fault, dividing the Eocene rock formation from the alluvial units of different ages. The rapid expansion of the city, especially during recent decades, necessitates the proper assessment of seismic hazard in the region.

Previous geological studies in the plain of Tehran have mainly focused on the identification and dating of various alluvium units (Rieben, 1955, Engalenc, 1968) and mapping of the major faults affecting the alluvium (Tchalenko et al., 1974; Tchalenko, 1975; Berberian et al., 1985; Berberian and Yeats, 1999). However, tectonic activity in the NTF has rarely been studied. A first paleoseismological study of the NTF carried out in its central part suggested a Holocene slip rate of approximately 0.3 mm/year (Ritz et al., 2012). The determination of recent fault slip rate is the key to evaluating the fault's earthquake potential.

Recent studies suggest a discrepancy between the geologic and geodetic slip rates along faults such as the San Andreas Fault System (Bird, 2009; Zeng and Shen, 2014, Tong et al., 2014), the Eastern California Shear Zone (Oskin et al., 2007), Walker Lane fault (Thatcher et al., 1999; Hammond et al., 2011), and Altyn Tagh fault (Cowgill et al., 2009). Since long-term slip rates estimated from geological data are subject to uncertainty, present-day geodetic measurements appear to be better suited to the task of estimating recent slip rates. Comparisons between geodetic and geologic slip rates are important because they represent slip rates observed over different time intervals. Consequently, understanding geologic–geodetic discrepancies could better define the spatial distribution of near-term seismic hazards. In this study, the geodetic slip rate of the NTF was estimated using precise leveling measurements. By inverting the leveling observations using simulated annealing optimization in a Bayesian framework (Amighpey et al., 2013), the fault creep rate and locking depth were estimated and compared with results from the aforementioned paleoseismological study (Ritz et al., 2012). The uncertainties of the results of the inversion were determined by computing the marginal a posteriori probability density function of a parameter and several orders of its moments.

2. North Tehran Fault geology

The North Tehran Fault (NTF) is a north-dipping fault marking the boundary in the north of Tehran between Eocene rock formations and alluvium (Fig. 1(a)). It marks the abrupt change of elevation between Tehran's piedmont and rock formation raising over 2.5 km above it. The fault has been interpreted in two different ways: as a left-handed en-echelon fault (Tchalenko, 1975) or as a continuous thrust fault, named the North Tehran Thrust (Berberian and Yeats, 1999).

The North Tehran Fault extends over approximately 110 km, with a general "V" shape trace at the surface, switching from an NW-SE

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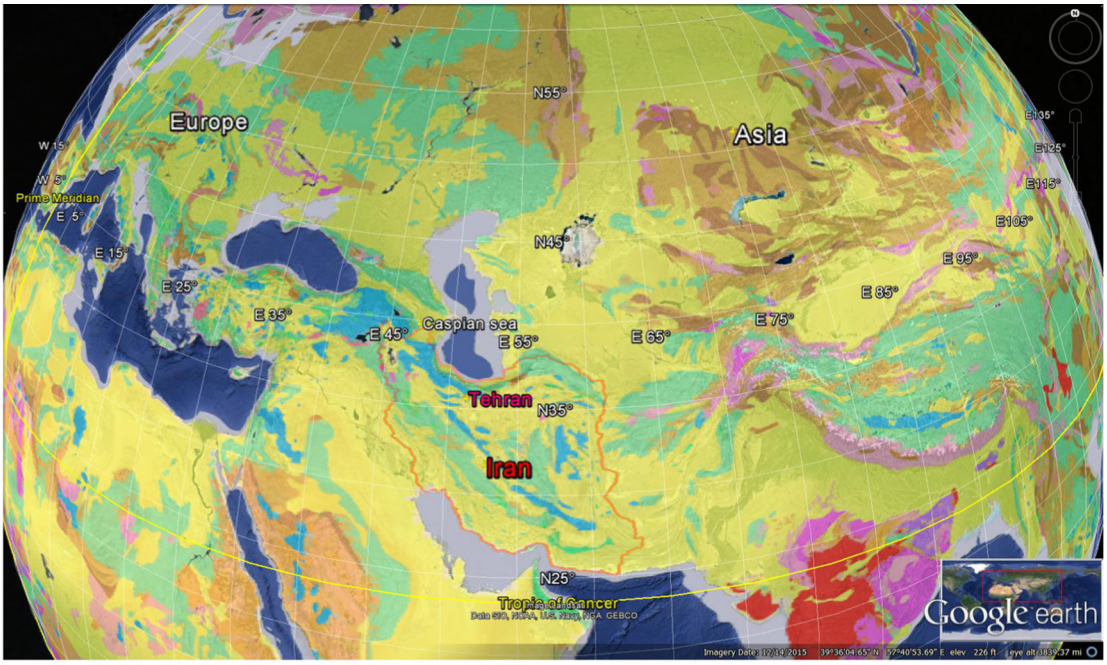
a)



b)

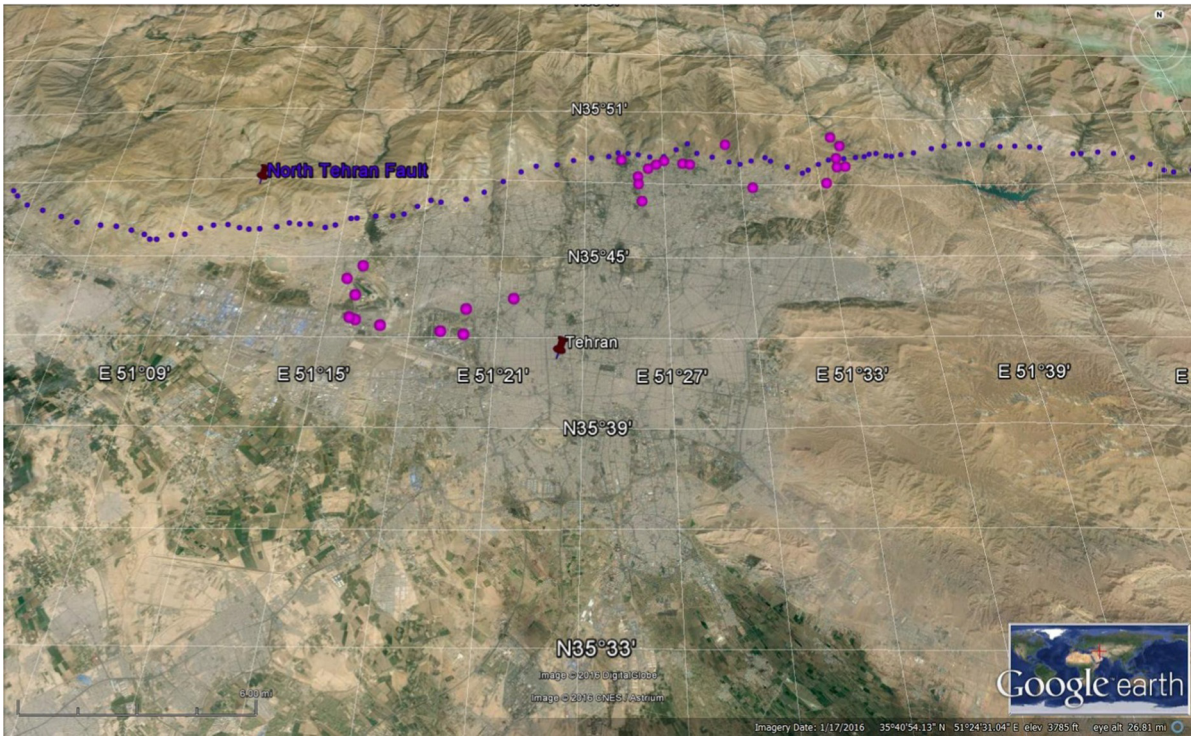


Fig. 1. (a) Location of the study area within world geological framework (World Commission for the Geological Map of the World, 2016). (b) North Tehran Fault (depicted by violet circle) and physiographic features of the Tehran. Precise leveling network is shown by pink circle color.

direction to a NE–SW one (Fig. 1(b)). The fault trace is, however, difficult to follow mainly because of urban development, and it appears to be divided into several segments (Nazari et al., 2011). It stands out as a major active fault menacing the city of Tehran, the capital city of Iran with a population of 12 million inhabitants.

Historical earthquakes have been used to assess seismic hazard in Tehran (Amberaseyas and Melville, 1982; Berberian, 1995). The last major event near Tehran occurred in 1830, causing damage to the northern part of this city (Amberaseyas and Melville, 1982). Previous studies suggest that the reactivation of the North Tehran Fault (NTF) led to this seismic activity (Tchalenko et al., 1974; Tchalenko, 1975; Berberian et al., 1985). Berberian and Yeats (1999) proposed that the historical earthquakes of 958 and 1665 can also be attributed to the fault system located immediately to the north of Tehran.